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Question: 1. What is the most effective way DOE could catalyze durable, bankable demand for clean hydrogen at DOE-funded H2 Hubs? Which of the following potential mechanisms would be most impactful?

1. ***Pay-for-difference contracts that provide support to projects based on the price they can achieve in the market***
2. ***Fixed level of support for projects (e.g., fixed $/kg amount) that stacks on top of other sources of revenue***
3. ***Funding to support feasibility analysis from potential offtakers near H2Hubs***
4. ***"Market-maker" for clean hydrogen to provide a ready purchaser/seller for clean hydrogen***
5. ***Other (please specify)***

A "market-maker" for clean hydrogen represents the most promising approach.

Pay-for-difference

A pay-for-difference contract offers subsidies to projects to cover the difference between the market price and some predetermined strike price. As a result, the producer gains complete price certainty–if the market price falls below the strike price, the government covers the difference; if the market price soars above the strike price, the producer will pay the government the difference. The advantage of this approach is that producers can invest more confidently without any price risk.

There are, however, some major disadvantages. For instance, a pay-for-difference contract runs into substantial challenges regarding identifying a market reference price. Specifically, merchant hydrogen markets tend to operate using bilateral contracts between a producer and an off-taker. The prices are separately negotiated, and are not transparently posted on an exchange. Moreover, these contracts may be relatively long-term and differ substantially by location (in part due to the difficulties of transporting hydrogen), meaning that identifying the "market reference price" that the government should benchmark their payments (or receipts) against may be difficult to ascertain.

There are several possible workarounds to a market reference price, but each is generally imperfect. One could attempt to determine such a price using market sales surveys, or estimates of production costs, but those each have their own separate issues: sales surveys run into the location and frequency challenge identified above and production costs will ignore changes in prices due to demand. A second option is to use the market price for natural gas (or 'gray' hydrogen) as the benchmark, as the UK does for its own hydrogen CfD (contract-for-difference) scheme. This approach has one drawback–the natural gas price is not exactly the same as the hydrogen price, even if the two are correlated–but it is likely the easiest and most accurate option available.

A second challenge is determining the strike price. The simplest method would be to run an auction, as done in the UK's renewable energy CfD scheme. The lowest strike price necessary to garner sufficient interest would determine the market. An alternative is to adopt the strategy proposed by the United Kingdom for hydrogen and use a firm-specific approach, negotiating bilaterally based on costs. In the short run, they will use an eligibility-based criteria to determine which firms will have access to the CfDs, but in the medium term they will transition to an auction-based approach. A bilateral, eligibility-based approach risks running into modest moral-hazard issues, whereby firms have little reason to choose lower marginal cost designs if higher capital and operational costs increase their strike price. The eligibility criteria could limit some of the more egregious cases of costly designs, but the lower incentive to ruthlessly economize on cost still exists so long as one can still meet the eligibility criteria. Moreover, there is a second moral-hazard problem whereby firms have little incentive to aggressively hunt for the best price in the market if they are guaranteed their strike price regardless. The UK's scheme attempts to sidestep this problem by instituting some cost sharing, thereby giving the firms some skin in the game, at the expense of undermining some of the price stability.

Fixed level of support

A fixed level of support would provide a set amount of money per kilogram of hydrogen sold for specific use cases. A fixed level of support for hydrogen production would largely duplicate the already large hydrogen production tax credit, without providing unique benefits. Providing support for specific demand projects on the basis of the number of kilograms of hydrogen used could also result in moral-hazard problems, where firms have less incentive to economize on the amount of hydrogen used in order to maximize their subsidy allotment.

Market maker

A market maker for clean hydrogen, much like the German Hintco or H2 Global scheme, seems more promising. The government could act as an intermediary, offering longer-term supplier agreements (e.g. 3-5 years) to hydrogen producers while issuing short-term off-take agreements to off-takers.

There are two advantages of the market-maker approach when compared to a payments-for-difference or CfD scheme:

1. A market maker helps directly create a commodity spot market, which a CfD (or direct subsidy) model does not. A spot market is a market where the commodity traded is for immediate delivery and stands in contrast to a futures market (where the product being traded will be delivered in the future) or a bilaterally negotiated private market. A spot commodity market in turn has several benefits, including more transparent pricing (since prices are posted on an exchange as opposed to opaquely negotiated bilaterally), lower barriers to entry to new users (since new users do not need to separately negotiate contracts and contract terms are standardized and transparent), and greater flexibility for new use cases (since a firm can attempt to use hydrogen for a use case without locking themselves into a long-term supplier-customer relationship).
2. A market maker eliminates counterparty risk in a way that a CfD (or direct subsidy) model does not. Off-takers may be wary of partnering with any specific new green hydrogen producer for fear of non-performance or production delays, since green hydrogen is a nascent field with little demonstration at scale. Short-term off-take agreements sold by the government (perhaps paired with a futures market in the future to mitigate pricing risk) limits that risk since (a) the off-taker does not have any long-term relationship with any specific supplier, and (b) any idiosyncratic plant-specific risks are spread across the entire set of firms with whom the government has contracted, so aggregate marketplace risks remain low. In a CfD or direct-subsidy model, off-takers would still need to bilaterally negotiate with specific suppliers, exposing them to some non-performance risk.

Eventually, this intermediary role could transition to the private sector. The theory of change may run as follows: initially, the bid-ask spread in the auction (the wedge between the price bid by hydrogen buyers and the price asked by hydrogen producers) will be quite large, so a net subsidy is required. Over time, as the production costs for clean hydrogen fall and the market for its use case broadens, that spread may shrink or even become slightly positive, and private intermediaries would become willing to become market makers themselves, as is the case in other commodities such as oil or wheat. If that is accomplished, the government subsidies would shrink to zero and equity and governance could be transitioned to private management through some competitive bidding process.

This approach helps solve the primary “cold-start” problems in creating an exchange. The biggest challenge in creating an exchange is concentrating enough buyers and sellers in one market such that one has enough liquidity to maintain competitive pricing. For new exchanges, that coordination is rather difficult: buyers do not want to join an exchange if there are few sellers, and sellers do not want to join an exchange with few buyers, since low participation rates from potential counterparties may lead to inferior pricing. In particular, participants may worry that they may leave a buy or sell order on an order book that may remain unmatched for a long period of time, exposing them to the risk that the price may move during that period. But the presence of a public market maker who is willing to pay a subsidy to cover the spread between buyer and seller prices may result in participants on both sides joining (since it eliminates that matching risk) even before knowing how many other participants there are in the market.

In contrast, the two primary benefits of a CfD or payments-for-difference scheme are similarly accomplished under a market maker model. Namely, in both the CfD and market maker model there is a subsidy for clean hydrogen to help bridge the cost gap between production costs and demand, and the subsidy is designed to provide long-term stability to the producer.

There are two categories of benefits in any hydrogen scheme: static and dynamic. A static benefit would be the direct emissions averted by using hydrogen instead of fossil fuels for any given purchase. The dynamic benefit is that each purchase helps incentivize investment and R&D in future hydrogen production that could result in even more emissions averted. In a well-designed scheme, the dynamic benefits should far exceed the static benefits.

As a result, it is critical that the $1 billion program make credible promises about its existence into the future in order to incentivize that development. A scheme that merely provides a subsidy to existing (or near-existing) producers may have static benefits (and some longer-term demonstration effects), but the primary dynamic effects would be reduced.

One concern may be that a spot-commodity market in any given hub may be too "thin" (insufficient producers or purchasers), resulting in collusive or non-competitive pricing. This thinness may result in the government taking on a large, unbounded liability if the price gap between sellers and buyers persists. The program designer should be careful to install reservation prices, perhaps in part pegged to auction pricing in other hubs, to limit the government's liability. Moreover, this risk remains symmetric with contracts-for-difference which, if they lack a floor, also face an unbounded risk should market prices fall. More formal modeling would be necessary to determine the optimal reservation price and auction design schema. Moreover, in both cases, the price of gray hydrogen operates as a soft floor on green hydrogen market prices, so there is some limit to the possible obligations of the government under either scheme.

Another tool to reduce the "thin markets problem" is to experiment with the frequency of auctions in the spot market. In a traditional central limit order book (as is used by the stock market and most commodity markets), bids and asks are continuously matched. The danger of this approach in a thin market is that liquidity at any given point in time might be quite low, so neither the seller nor the buyer knows if they are getting the best price possible by matching an order now or if they should wait until later. One alternative is to lower the frequency of matching. For instance, during overnight hours, the New York Stock Exchange collects bids and asks and only ultimately matches them at the opening bell. The London gold market only runs two auctions per day and does not match continuously. Program designers should formally model the optimal frequency of running these auctions–lower frequency may allow the market to function with lower liquidity, though may be less convenient for purchasers attempting to buy quickly.

Derivatives in a market-maker model

One weakness of a pure market-maker approach is that a spot market (where contracts are for immediate delivery) exposes end users to price volatility, since they cannot lock in a price long term. These end users can hedge this risk by long-buying natural gas futures (since the prices of hydrogen and natural gas will likely be correlated, but not identical), buying over-the-counter (i.e. bespoke, non-exchange-traded) risk-mitigation products with banks (with the corresponding high fees offered), or hoping that prices will continue to decline (which seems likely over the medium term, but may not hold true for month-to-month variation). None of those alternatives are perfect. Another weakness is that spot markets offer little long-term price transparency. One potential solution would be to offer commodity futures, as exist in other markets, where auctions could be run for future delivery. The danger is that a government exchange would be unable to sustain liquidity by running many different separate subsidized markets. The following model represents a rough idea to explore further: the key takeaway is that commodity futures and derivatives can be layered above a spot market without incurring additional subsidies, allowing firms to hedge their risk and providing greater price transparency.

Implementing commodity futures

So long as the underlying spot market is subsidized (as the government would bear the wedge between the long-term producer price and the short-term spot market price), the same government entity can host derivatives that can provide long-term price discovery without having to directly subsidize the derivative market. Here is how it might work:

- Party A is an end-user of hydrogen but wishes to hedge their pricing risk.
- Party A submits a bid to the exchange for delivery of 1 Kt of hydrogen 12 months from now. Party B (likely a financial intermediary) matches the order on the exchange, thereby obligating them to provide that hydrogen 12 months from now.
- Party A and Party B do not know who each other are; both are merely interfacing with an exchange.
- 12 months hence, Party B (or whoever Party B has sold its obligation to) will buy 1 Kt of hydrogen on the spot market and deliver it to the exchange which will deliver the hydrogen to Party A.

- Party B thus assumes the price volatility risk from Party A, in exchange for some small price premium.

Party A thus obtains the price stability it needs without the government providing a subsidy for a separate futures market (which could split liquidity and run into thin-markets problems). This model has three key advantages:

1. Long-term price stability for those who want it.
2. Long-term price transparency for producers, end-users, and government policymakers.
3. Increasing demand on the spot market, which previously may have a thin-markets problem, by making it the means of settling futures markets.

2. For eligible projects, what competitive process should be used to select projects that will receive demand-side support?

1. ***Reverse auction in which projects compete to bid the lowest level of support they need to make their project viable.***
2. ***Request for proposal-like process in which projects apply and are selected based on a variety of factors.***
3. ***Eligibility-based process in which all projects that meet certain threshold requirements receive some form of support.***
4. ***Other (please specify).***

As mentioned previously, a reverse auction represents the most promising approach.

In a request-for-proposal style regime, the government needs to pick specific firms to back based on a variety of criteria. Those varieties of criteria present opportunities for mistakes in judgment, as firms can game or obfuscate their true costs through an application. RFPs are not incentive-compatible: firms are not incentivized to reveal their true preferences and needs.

Regarding an eligibility-based process, opening up the subsidy to too many firms may result in a small level of support per firm and exhaust the $1 billion pool quickly, resulting in little incentive to innovate for future firms. Even specially setting aside funding for future years could result in a small per-firm subsidy, which would result in a similarly lower incentive to innovate. While there may be static and competition benefits of such an approach, since a broad eligibility-based process may result in more participants, the weakening of the dynamic innovation incentives of this scheme offered by the alternative approaches are likely to dominate those enhanced competition effects.

A reverse auction, by contrast, provides an incentive for firms to faithfully report their costs and needs through the subsidy scheme. It also minimizes cost to the government by selecting only the lowest-price firms. There are three risks worth addressing: first, thin markets. In this scenario, there is an insufficient number of bidders, resulting in an uncompetitive price. This problem can be ameliorated using a reserve price, possibly linked to the results of auctions in other hubs. Second, an auction will result in a purchase for the least-cost option today, which may not be the process that will produce the least-cost option in the future (imagine two technologies: one relatively cheap but with little room for costs to fall, and another that is more expensive but with a little learning-by-doing may become substantially cheaper). However, this risk may be smaller than the risk that introducing judgment calls (such as about the slope of future cost reductions) results in misallocation. Third, there is a risk that firms underbid ("race to the bottom") in the auction, and the winners of the auction are those that most underbid, resulting in the plants being unable to deliver at the promised level of subsidy. Moreover, bankruptcy limits the total downside for a firm, resulting in a further incentive to underbid. This risk however is far more severe in scenarios where all bidders face a common cost/revenue structure, and thereby any bid differences are not reflecting any private information. Since cost structures for bidders are likely very different, differences in bids are more likely to reflect differential levels of need rather than misjudgments about the level of subsidy required.

3. How can DOE design demand-side support to account for other kinds of support that H2Hubs projects may receive (e.g., tax credits, state and local government incentives, DOE cooperative agreement funding)?

The largest incentive provided is the Production Tax Credit, providing up to $3/kg of clean hydrogen. Supplemental demand efforts should attempt to differentiate themselves from the PTC and address areas that a PTC cannot quite handle. For instance, while the PTC certainly lowers the effective price of H_2, it does not address many of the barriers that make potential off-takers wary, such as non-performance risk at scale, or some of the remaining concerns of producers, such as price instability. As a result, a supplemental program should focus on those remaining gaps, such as the proposed market-maker program.

One of the principal benefits of the H2Hubs program is that by concentrating suppliers and producers within a limited geographic area, it may help reduce the transportation-cost burden, perhaps by enabling private buildout of hydrogen pipelines and other connective infrastructure. That concentration may also enable thicker markets, allowing for more competitive auctions should one choose to use a market-maker model.

4. How can DOE structure demand-side support for H2Hubs to best catalyze the formation of a mature commodity market for clean hydrogen?

1. ***How can DOE structure demand-side support for H2Hubs to best catalyze the development of standard contract terms for clean hydrogen?***

A market-maker model has a straightforward mechanism by which it could catalyze the development of standard contract terms: the government's standard off-take agreements could become Schelling points upon which other standard contract terms coalesce around. Prior to the existence of any commodity market, there is uncertainty about (a) which contract terms are essential versus preferred for off-takers, and (b) how to balance competing claims from separate off-takers about which contract terms they would accept. One efficient way to reduce that uncertainty is to run the auction for a period of time (e.g. a year), and be willing to quickly iterate for future years based on feedback from off-takers and producers about which details they wish or need to change. Iteration cannot be too frequent–future predictability is important to building market confidence and participation. But trying to perfectly optimize terms prior to the existence of the market may risk letting the perfect be the enemy of the good.

2. ***How can DOE structure demand-side support for H2Hubs to best catalyze the development of price transparency for clean hydrogen?***

The best way to catalyze the development of price transparency is to have contracts primarily executed on-exchange, rather than bilaterally over-the-counter. A mechanism to allow for commodity futures (as explained above) would allow for superior price discovery, as the price of the commodity future would allow for more incentive-compatible, market-sourced estimates of expected future prices. One danger of exclusively using a spot market is that off-takers face pricing risk that they do not equivalently face with long-term off-take agreements and they cannot hedge directly (it's possible to indirectly hedge this risk by purchasing the long side of a natural gas future, but there is still a wedge of risk between natural gas prices and hydrogen prices). Futures contracts send valuable signals to end-users, producers, and government policymakers that non-market-mechanisms cannot easily replicate.